10/577797

P803662/WO/1

IAP17 Rec'd PCT/PTO 28 APR 2006

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Directly injecting internal combustion engine

The invention relates to a directly injecting internal combustion engine with at least one cylinder which has a combustion space and in which a piston executes an oscillating movement, according to the type defined in more detail in the preamble of claim 1.

A generic internal combustion engine is known from US 2002/0117146 A1. In this case, the fuel is injected at a relatively steep injection angle into the combustion space, and the piston recess is adapted at least partially to the injection angle.

In an internal combustion engine described in DE 196 49 052 A1, a special shape of the piston recess is likewise provided, in order to achieve an additional reduction in the pollutants emitted by the internal combustion engine.

When early homogenization is to be achieved within the combustion space when an internal combustion engine, in particular a diesel internal combustion engine, is in operation, then injection time points of approximately 130 to 30° before the top dead center of the piston must be selected, since, at this time point, the combustion space pressure is still relatively low, so that the injected fuel can penetrate very deeply into the combustion space. In order to prevent the injection jet from impinging onto the cylinder wall or the liner, as steep an injection angle as possible at the injection nozzle should be selected, in order to ensure as long a free jet length as possible. This also requires the shape of the piston recess to be adapted to this injection, as is the case, for example, in

US 2002/0117146 A1.

Since, however, it is not possible to operate the internal combustion engine with a homogeneous combustion process over its entire characteristic map, the piston recess must be designed both for homogeneous and for conventional mixture formation. This is not easily possible in known solutions.

The object of the present invention, therefore, is to provide a directly injecting internal combustion engine, in which the shape of the piston recess is designed such that the internal combustion engine can be operated by means of both a homogeneous and a conventional combustion process.

This object is achieved, according to the invention, by means of the features mentioned in claim 1.

The solution according to the invention ensures that the injection jet always impinges on the piston recess such that the injected fuel can be intermixed optimally with the air located in the combustion space, specifically independently of the time point of injection. Particularly the fact that an injection jet injected at the latest possible time point always impinges onto the surface adjoining the elevation ensures that the momentum of the impinging injection jet is not nullified, with the result that it could no longer be used optimally for mixture formation, which, in turn, would entail an increased formation of black smoke.

An internal combustion engine is thus afforded which can easily be operated by means of both a homogeneous and a conventional combustion process.

Advantageous refinements of the invention may be

gathered from the subclaims. An exemplary embodiment of the invention is illustrated below, in principle, by means of the drawing in which:

fig. 1 shows an internal combustion engine according to the invention with a piston oscillating in a combustion space of the latter and with an injection jet impinging on the piston recess of the piston;

fig. 2 shows the configuration of the piston recess of the piston from fig. 1 in a first region;

fig. 3 shows the configuration of the piston recess of the piston from fig. 1 in a second region;

fig. 4 shows the configuration of the piston recess of the piston from fig. 1 in a third region;

fig. 5 shows the deflection of the injected fuel jet into that region of the piston recess which is illustrated in fig. 4;

fig. 6 shows the configuration of the piston recess of the piston from fig. 1 in a fourth region;

fig. 7 shows the air capture in a sixth region of the piston recess;

fig. 8 shows a first embodiment of a fifth region of a piston from fig. 1;

fig. 9 shows a second embodiment of a fifth region of a piston from fig. 1; and

fig. 10 shows a third embodiment of a fifth region of a piston from fig. 1.

Fig. 1 shows an internal combustion engine 1 which has a crankcase 2 and a cylinder head 3. Within the crankcase 2 of the internal combustion engine 1 is located at least one cylinder 4 which has a combustion space 5 and in which a piston 6 executes an oscillating movement in a way known per se. In the cylinder head 3 is arranged an injection nozzle 7 having a plurality of injection orifices 8 from which an injection jet 9 emerges. In the present case, the opening angle α of the injection jet 9 is relatively steep and lies in a range of between 50° and 120°. Thus, fuel is thereby injected directly into the combustion space 5, so that this is a directly injecting internal combustion engine 1.

Fig. 1 depicts two different injection jets, to be precise an injection jet 9a, which is obtained when the piston 6 is at a top dead center, and an injection jet 9b, which is obtained in the case of fuel injection at the latest possible injection time point. The injection jets 9a and 9b are in each case illustrated merely as axes of an injection cone being distributed within the combustion space 5.

The piston 6 has a piston recess 10 in its side facing the cylinder head 3. In the following figures, the contour of the piston recess 10 and its adaptation to the injection jets 9 are explained in more detail, for the sake of clarity the individual figures in each case indicating only those reference symbols which are relevant for describing the respective figure. The piston recess 10 is identical in all the figures.

As can be seen in fig. 2, the piston recess 10 has in its central region an elevation 11 extending in the direction of the cylinder head 3. The elevation 11 in this case has an angle β with respect of the axis of the piston which is smaller than half the injection

angle α, so that the outermost edge of the injection jet 9a, illustrated here as a mid-axis, does not come into contact with the elevation 11.

As can be seen in fig. 2 and fig. 3, the elevation 11 has adjoining it in the direction of a recess edge 12, that is to say the end of the piston recess 10, a surface 13 which is connected to the elevation 11 via a radius 14 in such a way that the injection jet 9a injected at the earliest possible time point impinges onto the surface 13 at an impingement point 15 and is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. This distribution of the injection jet 9a is important in order to intermix the fuel as effectively as possible with the air located in the combustion space 5. Owing to the above-described steeper angle β of the elevation 11, as compared with the injection angle α, there is still sufficient free space in the region from the impingement point 15 of the injection jet 9a on the surface 13 to the elevation 11 to ensure that the fuel quantity deflected in the direction of the elevation 11 can be effectively distributed. The fuel deflected in the direction of the elevation 11 is designated by the arrow 16, whereas the fuel deflected in the direction of the recess edge 12 is designated by the arrow 17. It can be seen here that the fuel quantity deflected or distributed in the direction of the recess edge 12 is greater than the fuel quantity deflected in the direction of the elevation 11. The radius 14 should be selected, in this respect, such that an accumulation of the fuel flowing back is avoided.

It can be seen in fig. 4 that the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 is of essentially planar design and has an ascending gradient in the direction of the recess edge 12. In other words, the surface 13 forms a plane which is at a

constant angle γ to the injection jet 9 over the entire maximum injection duration. The angle γ may be varied as a function of the required momentum deflection of an injection jet 9c in this case impinging in the middle region of the surface 13, the main momentum taking place in the direction of the recess edge 12, as already mentioned above. If appropriate, it may also be expedient for the surface 13 adjoining the elevation 11 in the direction of the recess edge 12 to have a curved design.

Fig. 5 illustrates by means of arrows 18 and 19 that, during the entire fuel injection, a smaller fraction of the injection jet 9 is thereby conducted in the direction of the elevation 11 and a larger fraction is thereby conducted in the direction of the recess edge 12. The arrow 18 in this case shows the fuel quantity conducted in the direction of the elevation 11, whereas the arrow 19 shows the fuel quantity conducted in the direction of the recess edge 12.

The distance of the surface 13 from the injection nozzle 7 should be selected such that the injection jet 9 can achieve a sufficiently free jet length and therefore an optimum jet velocity and the optimum momentum. Depending on the number of injection orifices 8 of the injection nozzle 7, an interaction of the fuel deflected on the piston recess 10 between two injection jets 9 is possible, thus additionally contributing to the capture of air in the combustion space 5. In addition, the division of the fuel may also be assisted by swirl.

Fig. 6 illustrates the injection jet 9b injected at the latest possible time point. In this case, it can be seen that the surface 13 has an extent in the direction of the recess edge 12 such that the injection jet 9b injected at the latest possible time point impinges

onto the surface 13. In this region, too, the surface 13 is designed in such a way that the injection jet 9b is distributed both in the direction of the elevation 11 and in the direction of the recess edge 12. The fuel quantity distributed in the direction of the elevation 11 is designated by an arrow 20 and the fuel quantity distributed in the direction of the recess edge 12 is designated by an arrow 21. Thus, a vertical impingement of the injection jet 9 on the piston recess 10 is prevented, and it is ensured that the momentum of the injection jet 9b is maintained.

It is apparent from fig. 7 that the surface 13 has adjoining it a surface 23 connected to the recess edge 12 via a radius 22. At the recess edge 12, a pinch gap region 24, as it may be referred to, at or above an upper surface 25 of the piston 6 occurs, which pinches the fuel/air mixture in the edge region in the direction of the piston recess 10 and thereby reduces the emission of hydrocarbons and carbon monoxide. The pinch gap region 24 selected should not be too large, since, even in this region, an air capture is required. The surface 23 contributes to the fact that the fuel jet following the arrow 21 is deflected such that an increased introduction of fuel into the pinch gap region 24 is prevented.

Figs 8, 9 and 10 illustrate various tie-ups of the surface 23 to the upper surface 25 of the piston 6.

In the embodiment according to fig. 8, the surface 23 connected to the recess edge 12 forms an acute angle with the upper surface 25 of the piston 6. The supply of fuel to a glow plug or spark plug, not illustrated, can thereby be improved.

In the version according to fig. 9, the surface 23 merges at a radius 26 into the upper surface 25 of the

piston 6.

Fig. 10 illustrates a version in which the surface 23 connected to the recess edge 12 forms an obtuse angle with the upper surface 25 of the piston 6.